CLAIMS

What is claimed is:

1. A system for measuring retardance of a sample, comprising

a sample region for receiving the sample;

a source of substantially circularly polarized illumination light;

illumination optics for directing the illumination light toward the sample region;

analysis optics for receiving incident light from the sample region;

a plurality of photodetector regions;

beamsplitting optics for dividing the incident light into a plurality of sub-beams and for directing each sub-beam to a respective one of the plural photodetector regions;

a plurality of elliptical polarizers disposed in the sub-beams for preferentially transmitting incident light whose polarization state lies within a distance ε of a chosen pole on a Poincare sphere; and

a processor for determining retardance from intensity signals generated at the photodetector regions onto which the sub-beams are directed.

2. The apparatus of claim 1, wherein the sample retardance is 50 nm or less.

3. The apparatus of claim 1, wherein the sample retardance is 10 nm or less.

4. The apparatus of claim 1, wherein ε is 35 degrees or less.

5. The apparatus of claim 1, wherein ε is 20 degrees or less.

6. The apparatus of claim 1, wherein the beamsplitting optics comprise a beamsplitter configured to operate by partial reflection at an interface for dividing the incident light into the sub-beams.

7. The apparatus of claim 6, wherein the beamsplitter is substantially polarization neutral.

8. The apparatus of claim 6, wherein the beamsplitter is a polka-dot type.

9. The apparatus of claim 1, further comprising an optical retarder disposed adjacent an entrance face of the beamsplitting optics for transforming the polarization state of light passing therethrough.

10. The apparatus of claim 1, wherein the beamsplitting optics comprises a plurality of prism facets which divide the incident light into the sub-beams according to the area of each facet.

11. The apparatus of claim 10, wherein the beamsplitting optics comprises a single prism with multiple facets.

12. The apparatus of claim 10, wherein the beamsplitting optics comprises an assembly of a plurality of prisms.

13 The apparatus of claim 10, wherein the elliptical polarizers are located between the sample region and the beamsplitting optics.

14. The apparatus of claim 10, wherein the beamsplitting optics are located between the sample chamber and the elliptical polarizers.

15. The apparatus of claim 1, wherein at least one of the plural elliptical polarizers comprises a linear polarizer and at least one optical retarder.

16. The apparatus of claim 15, wherein the optical retarder is an electrically variable retarder.

17. The apparatus of claim 16, wherein the electrically variable retarder is a liquid crystal cell.

18. The apparatus of claim 1, wherein at least one of the plural elliptical polarizers comprises a fixed linear polarizer and at least two retarder elements.

19. The apparatus of claim 18, wherein at least one of the retarder elements is electrically variable.

20. The apparatus of claim 18, wherein at least two of the retarder elements are electrically variable.

21. The apparatus of claim 1, wherein the plural detector regions comprise a plurality of detectors.

22. The apparatus of claim 1, wherein at least two of the plural detector regions comprise different regions on a single pixilated detector.

23. The apparatus of claim 1, wherein the illumination light source is a pulsed lamp.

24. The apparatus of claim 23, wherein the illumination light source is a flashlamp.

25. The apparatus of claim 1, wherein the illumination light source is operable to emit monochromatic light.

26. The apparatus of claim 25, wherein the illumination light source comprises a broadband light source and a filter.

27. A system for real-time imaging of retardance of a sample, comprising

a sample region for receiving the sample;

a source of substantially circularly polarized illumination light;

illumination optics for directing the illumination light toward the sample region;

analysis optics for receiving incident light from the sample region;

a plurality of photodetector regions;

beamsplitting optics for dividing the incident light into a plurality of sub-beams and for directing each sub-beam to a respective one of the plural photodetector regions;

a plurality of elliptical polarizers located in the sub-beams for preferentially transmitting incident light whose polarization state lies within a distance ε of a chosen pole on a Poincare sphere; and

a processor for calculating retardance from intensity signals generated at the photodetector regions onto which the sub-beams are directed;

wherein the sample is one of a biological cell, a tissue sample, and an oocyte.

28. The apparatus of claim 27, wherein the sample is an oocyte.

29. The apparatus of claim 27, wherein the beamsplitting optics comprise a beamsplitter configured to operate by partial reflection at an interface to divide the incident light into the sub-beams.

30. The apparatus of 27, wherein the beamsplitting optics comprise a plurality of prism facets which divide the incident light into the sub-beams according to the area of each facet.

31. The apparatus of claim 29, further comprising a waveplate located between the sample region and the beamsplitting optics.

32. The apparatus of claim 30, wherein the plural elliptical polarizers are located between the sample region and the beamsplitting optics.

33. The apparatus of claim 30, wherein the plural prism facets comprise a single prism with multiple facets.

34. The apparatus of claim 30, wherein the plural prism facets comprise an assembly of a multiplicity of prisms.

35. A system for measurement of polarization, comprising

an incident beam of light to be measured

a multiplicity of photodetector regions;

a beamsplitter for splitting the incident light into plural sub-beams and for directing each of the plural sub-beams toward a different one of the multiple photodetector regions, said beamsplitter comprising a single multifaceted optical element;

a plurality of analyzer polarizers for preferentially transmitting incident light in a specified polarization state; and

calculation means for determining polarization state from signal levels generated at the plural photodetector regions onto which the plural sub-beams are directed.

36. The system of claim 35, wherein the plural analyzer polarizers preferentially transmit incident light in preferential incident polarization states corresponding to states within a distance ε of a selected pole on a Poincare sphere.

37. The system of claim 36, wherein ε is 35 degrees or less.

38. The system of claim 36, wherein ε is 20 degrees or less.

39. The system of claim 35, wherein at least one of the plural analyzer polarizers preferentially transmits incident light that is substantially circularly polarized and at least another of the plural analyzer polarizers transmits light that is substantially linearly polarized.

40. A method for imaging retardance of a sample in real-time, compriseing the steps of:

illuminating the sample with light that is substantially circularly polarized;

receiving light that has interacted with the sample;

dividing the received light into N sub-beams, where $N \geq 2$;

disposing elliptical polarizers in the N sub-beams, corresponding to states within a distance ε of a pole on a Poincare sphere;

analyzing a polarization state of each of the N sub-beams with the elliptical polarizers;

forming an image of the sample with each sub-beam;

measuring intensity at a plurality of points in the image at each of the N sub-beams; and

calculating the sample retardance based on the N image intensity measurements.

41. The method of claim 40, further comprising the step of calculating a principal slow axis of the sample at a plurality of points.

42. The method of claim 40, further comprising the step of taking a background measurement with no sample present.

43. The method of claim 40, wherein N is 5.

44. The method of claim 40, wherein N is 4.

45. The method of claim 44, wherein one of the elliptical polarizers preferentially transmits received light that is substantially circular in polarization state.

46. The method of claim 44, wherein none of the elliptical polarizers preferentially transmit received light that is substantially circular in polarization state.

47. The method of claim 40, wherein N is 3.

48. The method of claim 40, wherein N is 2.

49 The method of claim 40, wherein at least one of the elliptical polarizers is electrically variable.

50. The method of claim 42, further comprising the step of storing background data derived from the background measurement.

51. The method of claim 50, further comprising the step of correcting the calculation of retardance using the stored background data.

52. The method of claim 40, further comprising the step of taking calibration images to compensate for variations between optical responses of the N sub-beams.

53. The method of claim 52, further comprising the step of correcting the image intensity measurements using the calibration images.

54. The method of claim 52, wherein one of the polarization of the illumination light and the preferential polarization state of at least one of the polarizers is altered between the calibration measurement and the sample measurement.

55. The apparatus of claim 27, further comprising a display unit for providing an image of the sample retardance.

56. The apparatus of claim 55, wherein the display comprises a head-up display.

57. The apparatus of claim 57, wherein the sample is viewable with a microscope and wherein the image of sample retardance provided by the display comprises an image viewed from within the eyepiece of the microscope.